

COST AND PERFORMANCE REPORT

EXECUTIVE SUMMARY

This report summarizes cost and performance data for a soil vapor extraction (SVE) treatment application at the Well Number 3 Subsite of the Hastings Groundwater Contamination Superfund site. Soil at the site was contaminated with halogenated organic compounds. Contamination was attributed to spills of carbon tetrachloride (CCl_4) which had been used in the 1960s and 1970s as a fumigant at a grain storage facility. Concentrations of CCl_4 were measured in the soil gas at the site at levels over 1,200 ppmv.

On September 26, 1989, a Record of Decision (ROD) was signed to implement SVE as an Interim Source Control measure. EPA and the Nebraska Department of Environmental Quality established an extraction rate for CCl_4 of 0.001 lb/hr as the cleanup goal, with operation of the SVE system required until field analytical results were verified through laboratory analysis and it was confirmed that no rebounding of CCl_4 was occurring.

A pilot-scale SVE treatability study was conducted from April to May 1991. The pilot-scale system included 2 deep and 2 shallow extraction wells. During the pilot-scale opera-

tion, 45 pounds of CCl_4 were removed. The full-scale SVE system consisted of 10 extraction wells (5 deep, 3 intermediate, and 2 shallow), 5 monitoring well probes, an air/water separator, a vacuum pump, and vapor phase granular activated carbon (GAC). The full-scale system design included the two deep extraction wells and one of the shallow extraction wells used in the pilot-scale study.

The SVE system was operated from June 25, 1992 to July 1, 1993 to treat approximately 185,000 cubic yards of soil. The SVE system achieved the 0.001 lb/hr CCl_4 extraction rate within 6 months, with confirmation of analytical results and no rebounding of CCl_4 by July 1993.

Actual costs for installing and performing the SVE application, including disposal costs for the GAC, were approximately \$370,000, which corresponds to \$620 per pound of CCl_4 removed (600 pounds removed) and \$2.00 per cubic yard of soil treated. This large-scale project benefited from treatment of soil with relatively low levels of contaminants in the soil gas.

SITE INFORMATION

Hastings Groundwater Contamination Site
Well Number 3 Subsite
Hastings, Nebraska
CERCLIS # NED980862668
ROD Date: 9/26/89

Treatment Application: Remedial
Treatability Study Associated with Application? Yes (see Appendix A)

EPA SITE Program Test Associated with Application? No

Period of Operation: 6/25/92 - 7/1/93

Quantity of Material Treated During Application: 185,000 cubic yards of soil (based on an estimate provided by the vendor of an areal extent of contamination equal to 40,000 ft^2 and a depth of contamination equal to 125 ft) [21]

Background

Historical Activity that Generated Contamination at the Site: Grain fumigation

Corresponding SIC Code(s): 0723A (Crop Preparation Services for Market, Except Cotton Ginning - Grain Fumigation)

Waste Management Practice that Contributed to Contamination: Spill/contaminated aquifer



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SITE INFORMATION (CONT.)

Background (cont.)

Site History: The Hastings Groundwater Contamination Superfund site (Hastings) is located in Adams County, Nebraska, as shown in Figure 1. The site was used as a grain storage facility in the 1960s and 1970s. During this time, carbon tetrachloride (CCl_4) was used as a fumigant and spillage resulted in soil and groundwater contamination at the site. As shown in Figure 2, the site consists of several contaminant source areas referred to as subsites. The Well Number 3 Subsite is the location of a CCl_4 groundwater contaminant plume and CCl_4 soil contamination extending from the water table to near the surface of the subsite. Contamination was detected in samples of the public water system of Hastings collected by the Nebraska Department of Health (NDOH) in 1983 in response to citizen complaints. Also in 1983, NDOH and the Nebraska Department of Environmental Quality (NDEQ) began to study groundwater contamination in Hastings. EPA began quarterly sampling of wells in 1985. From 1986 through 1989, EPA performed soil gas surveys to identify and characterize the suspected source areas. [1]

Regulatory Context: [1, 20, 22] On September 26, 1989, a ROD was signed by EPA for Interim Source Control Operable Unit 7, the

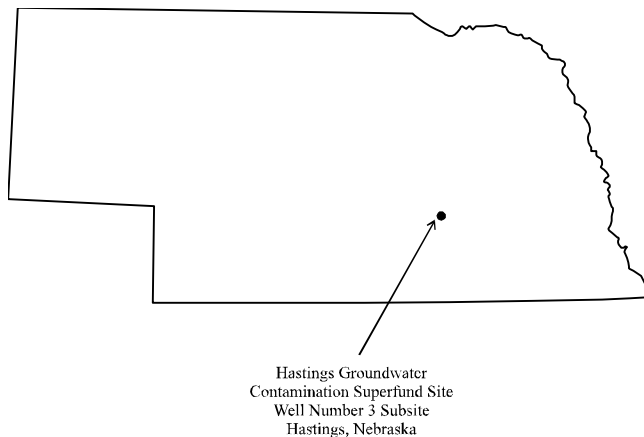


Figure 1. Site Location [1]

Well Number 3 Subsite. Soil vapor extraction, followed by air emissions treatment with granular activated carbon (GAC), was selected as the most appropriate source control action to protect public health and the environment by controlling and reducing the migration and volume of the contaminants present at the site. The ROD also specified: off-site regeneration or incineration of the GAC at an approved treatment facility; monitoring of the contaminants in the soil above the aquifer; groundwater monitoring; and monitoring of the air emissions from the GAC treatment.

Site Logistics/Contacts

Site Management: Fund Lead
Oversight: EPA

Remedial Project Manager:
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State Contact:
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Treatment System Vendor:
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Morrison-Knudsen Corporation
7100 East Bellevue Avenue
Suite 300
Englewood, CO 80111
(303) 793-5089



SITE INFORMATION (CONT.)

Background (cont.)

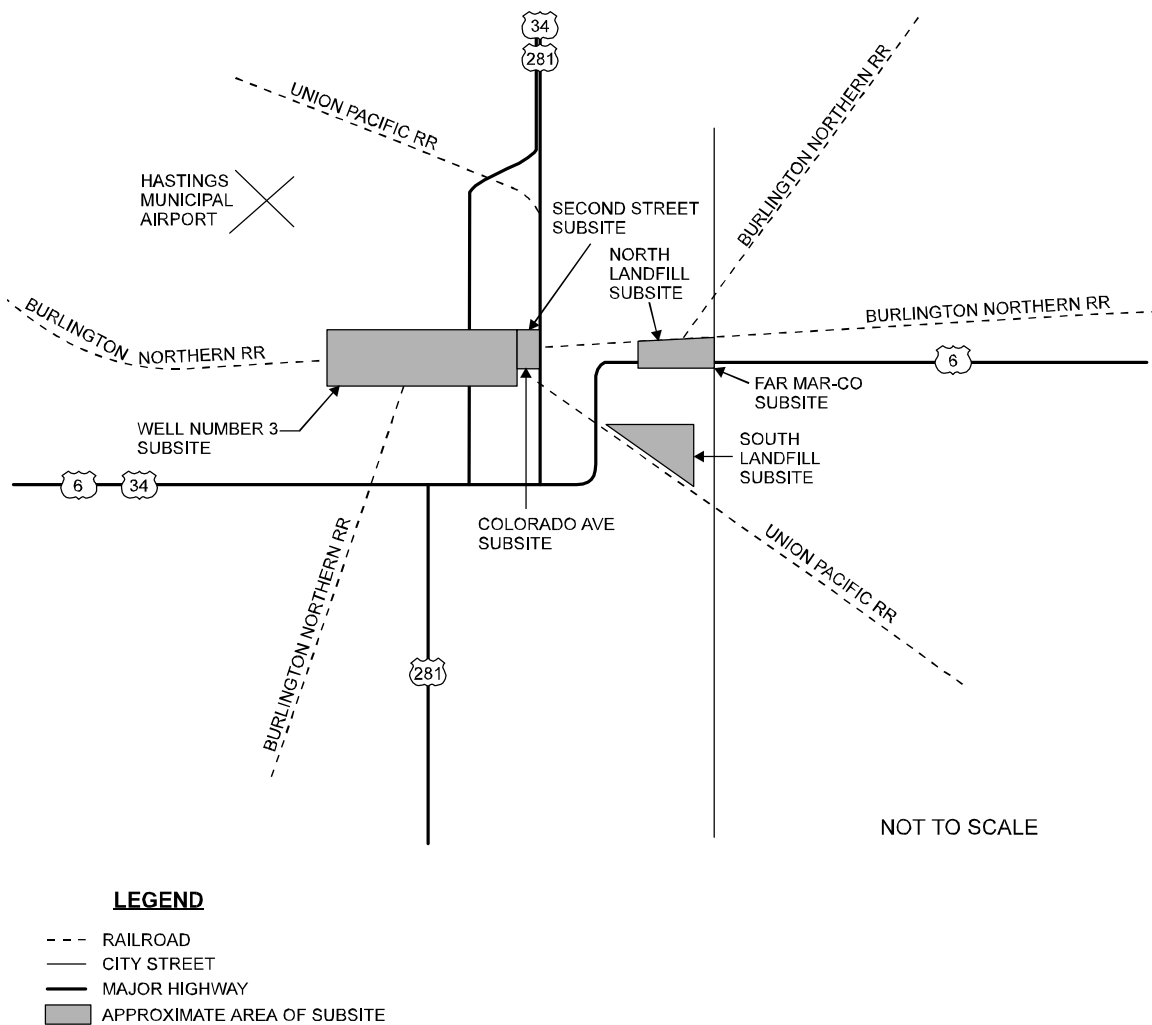


Figure 2. Hastings Groundwater Contamination Site [20]



MATRIX DESCRIPTION

Matrix Identification

Type of Matrix processed through the treatment system: Soil (in situ)

Contaminant Characterization

Primary contaminant groups:

Halogenated Volatile Organic Compounds

The primary contaminant identified in the soil at the Well Number 3 Subsite was carbon tetrachloride (CCl_4). Other contaminants identified at the site included chloroform, trichloroethene (TCE), 1,1-dichloroethane (DCA), 1,1,1-trichloroethane (TCA), and tetrachloroethene (PCA).

The results of soil gas surveys conducted by EPA at the site and shown in Figure 3, indicate that the highest CCl_4 concentration measured in the soil gas was 1,234 ppmv at 112 feet below the ground surface. In addition, CCl_4 concentrations were highest at depths of greater than 40 feet below ground surface. [1, 2]

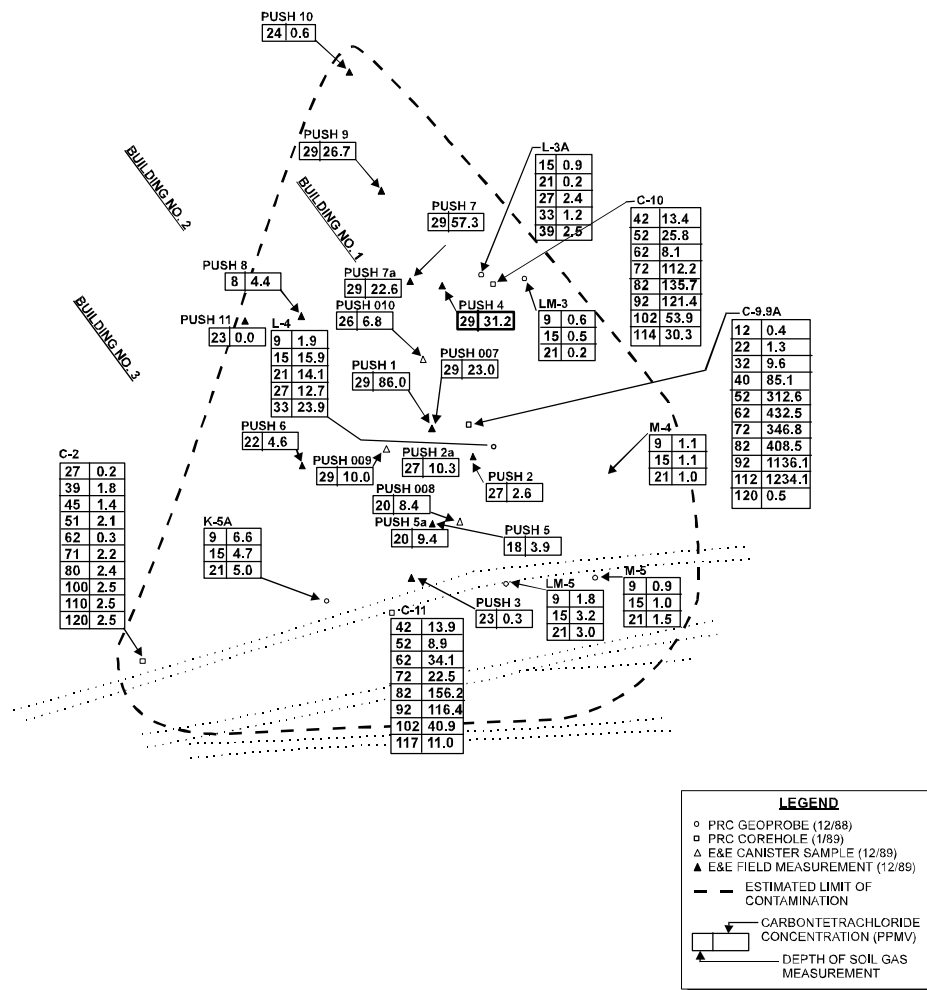


Figure 3. Soil Gas Concentrations [1]



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MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Cost or Performance

The major matrix characteristics affecting cost or performance for this technology and their measured values are presented in Table 1. A particle size distribution as determined by

the Unified Soil Classification System (USCS) for soils at 20 and 100 feet below ground surface (BGS) is shown in Table 2.

Table 1. Matrix Characteristics [4]

Matrix	Characteristic	Value	Measurement	Method
Soil	Classification	Not Available	—	
Particle	Size Distribution	See Table 2	Unified Soil Classification System (USCS)	
Moisture	Content*	26.3% at 20 feet BGS	Not Available	
		5.0% at 100 feet BGS	Not Available	
Air	Permeability	1.9 x 10 ⁻⁶ cm ² (shallow zone)**	Gas Tracer Test	
		6.2 x 10 ⁻⁶ cm ² (deep zone)**		
Porosity		Not Available	—	
Total Organic Carbon*		270 mg/kg at 20 feet BGS	Not Available	
		<50 mg/kg at 100 feet BGS	Not Available	
Nonaqueous Phase Liquids		Not Available	—	
Depth to Groundwater		125 feet BGS	Field	Measurement
Depth of Contamination		125 feet BGS	Field	Measurement

*Moisture Content and Total Organic Carbon results are from samples collected from soil boring of extraction well SVE-1D.

**"Shallow zone" is defined as 0-65 feet BGS; the "deep zone" is defined as >65 feet BGS.

Table 2. Particle Size Distribution of Soil Samples from the Hastings Well Number 3 Subsite [4]

Soil Type	Depth	
	20 Feet BGS	100 Feet BGS
Gravel	0.00%	0.00%
Coarse Sand	0.10%	9.30%
Medium Sand	0.00%	8.60%
Fine Sand	1.50%	51.80%
Very Fine Sand	2.00%	23.40%
Silt	73.70%	6.90%
Clay	22.60%	0.035%

Site Geology/Stratigraphy

The Hastings site is underlain by two distinct fluvial lithologies consisting of unconsolidated sands, silts, and gravels of the Pleistocene and Pleistocene/Miocene ages. The upper fluvial unit consists of a poorly-graded fine sand to silty clay sand while the lower fluvial unit

consists of well-graded medium to coarse gravelly sand. The water table is situated in the lower unit at a depth of approximately 125 feet below ground surface. A stratigraphic cross section of the site is presented in Figure 4. [3, 4]



MATRIX DESCRIPTION (CONT.)

Figure 4. Stratigraphic Cross Section [4]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Soil vapor extraction

Supplemental Treatment Technology

Post-treatment (air) using carbon adsorption

Soil Vapor Extraction System Description and Operation [2, 3, 4]

System Description

The SVE system used at the Hastings Well Number 3 Subsite consisted of 10 extraction wells (5 deep, 3 intermediate, 2 shallow), five monitoring well probes, and associated vacuum and air treatment equipment. The location and depth of these wells are presented in Figure 5 and Table 3, respectively. Extraction wells were installed at different depths to capture the vertical extent of the contamination which ranged from the ground surface to the water table. The extraction wells were constructed with 4-inch diameter, schedule 80 polyvinyl chloride (PVC) pipe, with 0.01-inch PVC screen. The intermediate and deep extraction wells were installed in pairs (three sets of collocated wells) approximately 5 feet apart.

Full-scale system design was based on the results of the pilot-scale treatability study (Appendix A) along with information on the site geology and the results of a pump test. The two deep extraction wells and one of the two shallow extraction wells used in the treatability study were utilized for the full-scale application. One shallow extraction well used in the treatability study was capped and abandoned because the well interfered with placement of the activated carbon canisters. Additional wells added for the full-scale application included one shallow well, three intermediate wells, and three deep wells.

For each well pair, the screened interval of the intermediate well was 50 to 80 feet below ground surface (bgs), and 80 to 110 feet bgs for the deep wells. This configuration allowed



TREATMENT SYSTEM DESCRIPTION (CONT.)

Soil Vapor Extraction System Description and Operation [2, 3, 4] (cont.)

Figure 5. Location of Extraction and Monitoring Wells [2]

Table 3. Status of Extraction and Monitoring Wells [3]

Well Type	Well No.	Status*	Screened Interval (In Feet Below Ground Surface)
Deep Extraction	SVE-1D	Used in TS and FS	103-113
	SVE-2D	Used in TS and FS	110-115
	SVE-4D	Installed for FS	80-110
	SVE-5D	Installed for FS	80-110
	SVE-6D	Installed for FS	78-108
Intermediate Extraction	SVE-4I	Installed for FS	50-80
	SVE-5I	Installed for FS	50-80
	SVE-6I	Installed for FS	50-80
Shallow Extraction	SVE-1S	Used in TS and FS	20-40
	SVE-2S	Abandoned from TS	30-40
	SVE-3S	Installed for FS	20-40
Monitoring	MP-1P	Used in TS and FS	55, 70, 110, 120
	MP-1S	Used in TS and FS	10, 30, 40
	MP-2	Installed for FS	50, 70, 90, 110
	MP-3	Installed for FS	50, 70, 90, 110
	MP-4	Installed for FS	50, 70, 90, 110

*TS - Treatability Study

FS - Full-Scale Operation



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TREATMENT SYSTEM DESCRIPTION (CONT.)

Soil Vapor Extraction System Description and Operation [2,3,4] (cont.)

selective operation of the wells at higher vacuum/flow conditions than could be achieved through one well.

Each extraction well was installed with a vacuum gauge to monitor well head conditions and a butterfly valve to throttle the well head vacuum and select use of the 30-foot screened well. The extraction wells were hard piped to the extraction and treatment system with heat traced and insulated PVC pipe, as shown in Figure 6.

The extraction and treatment system consisted of an air/water separator, an air-to-air heat exchanger, a vacuum pump, and vapor phase granular activated carbon (GAC). The

extraction system components were mounted on a process skid which included a flow metering piping run where the temperature, pressure, and flow rate of the extracted gas were monitored. The configuration of the equipment on the process skid and the arrangement of the system are shown in Figure 7.

The system included six 1,000-pound canisters of GAC, configured in two stages of three canisters each. When spent, carbon canisters were transported to a regeneration facility in Parker, Arizona. The treated vapors were discharged to the air through a 20-foot high steel stack.

Figure 6. SVE System Site Layout [2]



TREATMENT SYSTEM DESCRIPTION (CONT.)

Soil Vapor Extraction System Description and Operation [2, 3, 4] (cont.)

Figure 7. Process Area General Arrangement [2]

System Operation [2,6]

The SVE system was operated from June 25, 1992 to July 1, 1993 for a total of 6,600 hours. During operation of the SVE system, selective use of the extraction wells occurred, depending on the results of vapor samples collected at the individual wellheads. Additionally, the entire system was temporarily shut down when the overall extraction rate was less than the required cleanup extraction rate, carbon breakthrough occurred, or a sampling event occurred. A chronology of the SVE operations, including a description of activities, is presented in Table 4.

Depending on the number of wells being pumped at a given time, the total air flow rate ranged from 519 to 754 standard cubic feet per minute and the extraction well head vacuums ranged from 3.05 to 7.6 inches of mercury.

A detailed description of the SVE operation is presented below [22]:

June-July 1992: The initial operations of the SVE system focused on the "heart" of the contaminated area using extraction wells SVE-1S, -1D, -3S, -5I, and -5D. SVE modeling results indicated that the SVE system at the Well Number 3 Subsite would not generate enough vacuum to effectively remove contaminants if all extraction wells were opened. Initially, the plan was to extract from this area, then to extract from the fringes (extraction wells SVE-4I, -4D, -6I, and -6D), modifying the gas flow pattern as to when wells were opened and closed. This operation plan was unsuccessful because the high vacuum generated by pumping only on the interior wells, drew water into the SVE system, which resulted in a system shutdown. On July 1, 1992, system operation included all extraction wells. The SVE system was operated for 789 hours with vacuum on all wells. The concen-



TREATMENT SYSTEM DESCRIPTION (CONT.)**Soil Vapor Extraction System Description and Operation [2, 3, 4] (cont.)**

Table 4. SVE System Operations Chronology [6]

Date	Time	Cululative Down Time (hrs)	Cululative Elapsed Run Time (hrs)	Description
06/25/92	11:30	0	0	Start-up full-scale operation with extraction wells SVE-1S, -1D, -3S, -5I, and -5D open.
07/01/92	11:05	3.8	140	Opened remaining wells (SVE-4D, -4I, -6D, and -6I) to reduce excessive water
07/22/92	15:40	5.2	647	Wells SVE-1S and -3S were taken out of service since no contamination was being detected in samples.
07/26/92	14:55	6.3	789	Entire system shut down for 9 days to evaluate VOC rebounding effects.
08/06/92	12:00	198	810	The system was restarted with all wells pumped.
08/10/92	08:20	198	903	Wells SVE-1S, -3S, and -4I were taken out of service because no contamination was being detected in samples.
09/17/92	22:52	211	1816	System shut-down due to carbon breakthrough.
10/10/92	15:45	759	1816	System start-up after carbon replacement with all wells being pumped.
10/13/92	18:00	759	1890	Spent carbon shipped to TSD Facility.
10/19/92	10:20	760	2027	Wells SVE-1S, -3S, and -4I were taken out of service because no contamination was being detected in samples.
11/04/92	09:30	760	2409	Operation of the carbon system was changed to two stages of two adsorbers per stage.
11/28/92	20:45	760	2996	System shut-down due to concentration of CCl ₄ in composite carbon outlet exceeding the concentration of CCl ₄ in the carbon inlet.
11/30/92	17:00	780	3020	Restart SVE system.
12/21/92	09:40	780	3517	Granular activated carbon was removed from the system. EPA and NDEQ determined that the risk attributed to air emissions were low and that the GAC should be removed.
01/04/93	09:30	781	3852	System shut down for two months because extraction rate below 0.001 lb/hr CCl ₄ .
02/06/93	13:20	1577	3852	System start-up for sample collection only.
02/06/93	14:20	1577	3853	System shut-down after sample collection.
03/04/93	13:08	2200	3853	System start-up with extraction wells SVE-1D, -1S, -3S, -5I, -5D open.
03/24/93	11:15	2207	4325	Opened remaining wells (SVE-4D, -4I, -6D, and -6I).
04/29/93	9:15	2208	5188	Closed extractions wells SVE-3S and -4I to increase the vacuum at SVE-5D.



TREATMENT SYSTEM DESCRIPTION (CONT.)

Soil Vapor Extraction System Description and Operation [2, 3, 4] (cont.)

tration level of CCl_4 in the gas stream collected at the system inlet (S-101), dropped from 140 $\mu\text{g/L}$ to 13 $\mu\text{g/L}$ as measured in the EPA analysis of the 6-L SUMMA™ canisters. On July 26, 1992, the system was shut down for 9 days to evaluate VOC rebounding effects.

August-September 1992: On August 6, 1992, the system was re-started (all SVE wells) to determine rebounding effects. The analytical results indicated that there was little or no rebounding. The system was operated, pumping on all extraction wells which contained CCl_4 , until September 17, 1992 (1,027 hours) when the system was shut down to replace GAC.

October-January 1993: The system was restarted on October 10, 1992 and operated continuously until January 4, 1993 (an additional 2,036 hours). In November, additional peaks in the sample analyses were noted by the on-site analyst. The on-site analytical system used an electron capture detector which is sensitive to chlorinated solvents. SUMMA™ canister samples were collected from the wellhead locations from where these extra peaks were noted (S-101 and SVE-5D) on November 23, 1992 and sent to the EPA-Region VII laboratory. Analysis of these samples confirmed the presence of other VOCs in the system.

In December 1992, several operational changes took place. The NDEQ determined that, due to the low levels of VOCs present in the SVE gas stream, the GAC could be removed, and EPA and the NDEQ set an extraction rate remediation goal for CCl_4 at 0.001 pounds/hour. This level would need to be achieved based upon pulsed pumping, and verified with soil-gas sampling using SUMMA™ canisters. The SVE system was shut down on January 4, 1993 for a two-month resting period.

February 1993: Gas samples were collected on February 6, 1993 for both on-site and EPA analyses. The EPA results indicated that the

levels of other VOCs increased in SVE-5D, while the levels of CCl_4 remained low. Gas samples were collected during very cold weather which could have affected the results. SUMMA™ canister samples were believed to be less affected by the low temperatures than the syringe samples.

March 1993: The system was re-started with pumping from wells SVE-1S, -1D, -3S, -5I, and -5D. Samples were collected with SUMMA™ canisters on March 4 and 6 to determine rebounding effects. Some inconsistencies between on-site and off-site analysis were noted. There are several reasons why these inconsistencies may have occurred including: (1) sample size (10-mL syringe vs. 6-L SUMMA™ canisters); (2) temperature effects on collection method; and (3) low contaminant concentrations. On March 24, extraction wells SVE-4I, -4D, -6I, and -6D were added to the system.

April-June 1993: EPA and NDEQ agreed that the system would run continuously until analytical results could be verified, or until July 1, 1993. All extraction wells were being pumped. A final inspection of SVE system operation took place on April 19, 1993. On April 29, 1993, two extraction wells were removed from the system (SVE-3S and -4I) to increase flow to SVE-5D. Collection of verification samples was conducted on May 1, 1993 with the collection of SUMMA™ canister samples from SVE-5D and S-101 (system inlet). On-site testing results indicated that the CCl_4 levels remained low. Off-site EPA analyses of samples indicated that the on-site, field method has a negative bias of approximately 50%.

Post-June 1993: SVE skid equipment was dismantled and moved to EPA's storage area in Hastings, Nebraska. EPA abandoned all SVE extraction wells and monitoring probes. The chain-link fence has been reconfigured to accommodate the groundwater treatability study system.



TREATMENT SYSTEM DESCRIPTION (CONT.)

Operating Parameters Affecting Treatment Cost or Performance

The major operating parameters affecting cost or performance for this technology and the values measured for each are presented in Table 5.

Table 5. Operating Parameters [6-19]

Parameter	Value
Air flow rate	504 to 858 scfm
Operating vacuum	3.05 to 7.6 inches of Hg

Timeline

A timeline for this application is shown in Table 6.

Table 6. Timeline [1, 2, 4, 6]

Start Date	End Date	Activity
06/10/86	—	Site placed on NPL
09/26/89	—	ROD for Operable Unit 7 signed
04/15/91	05/09/91	Treatability test performed
02/92	03/92	Installation of additional full-scale extraction and monitoring wells
03/92	06/92	Procurement and fabrication of the vacuum extraction equipment
04/92	06/92	On-site construction of extraction and treatment system
06/25/92	07/01/93	Full-scale operation of SVE

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [1,5]

No cleanup levels were specified in the 1989 ROD. The remedial action at the Well Number 3 Subsite was completed as an interim measure for the purpose of controlling contaminant migration. In December 1992, EPA and the Nebraska Department of Environmental Quality established an extraction rate for carbon tetrachloride of 0.001 lbs/hr as a cutoff value for terminating operation of the SVE system. The rationale for the cutoff was supported by a cost comparison with ground-

water extraction and treatment. For extraction rates less than the cutoff value, groundwater extraction and treatment at this site was found to be less expensive than SVE.

In addition, EPA determined that the system was to be operated until the field analytical results were verified through laboratory analysis and it was verified that no rebounding of CCl_4 was occurring.



TREATMENT SYSTEM PERFORMANCE (CONT.)

Treatment Performance Data [2, 3, 6, 21, 22]

Treatment performance data for operation running time, air flow rates (Q_s), mass extraction rate, and total mass removed for carbon tetrachloride for this SVE system are shown in Table 7. Figures 8 and 9 show the mass extraction rate and cumulative mass removed for carbon tetrachloride, respectively, plotted against time for the operation of the SVE system. These data are based on field analytical results. The rate and mass were calculated from the concentrations of extracted vapor samples collected at the carbon system inlet. Samples of the extracted vapor were collected weekly using a gas-tight syringe and analyzed on site with a gas chromatograph for carbon tetrachloride only. [2, 3, 6]

Table 8 presents the carbon tetrachloride concentrations measured at each wellhead and the carbon system inlet. Sampling occurred at each extraction well on a monthly

basis with analyses performed on site. On a periodic basis, samples from the wellheads and carbon inlet were collected in stainless steel SUMMA™ canisters and were analyzed by a Region VII laboratory for volatile organic compounds (VOCs). The canister sampling results, presented in Table 9, were used to compare with the syringe sample results and to quantify other VOCs that may be present.

Post-treatment sampling of the soil gas or soil borings was not performed because of difficulties with detecting VOCs in soils at the site. Soil samples collected during the previous investigations frequently showed non-detects in locations where significant levels of soil gas were found. Therefore, it was concluded that soil gas was a more reliable and easily measured indication of vadose zone contamination.

Table 7. SVE System Operation Log [6]

Date	Time	Down Time (min)	Q_s (scfm)	CCl ₄ @ S-101 (ug/L)	Corrected CCl ₄ @ S-101 (ug/L)	Time of Operation (hrs)	CCl ₄ Extraction Rate (lb/hr)	Total CCl ₄ Removed (lb)
6/25/92	11:30					0.00		
6/25/92	11:52	0	771	48.00	88.80	0.37	0.256	0.09
6/26/92	08:45	190	728	111.00	205.35	18.08	0.560	10.02
6/27/92	7:30	15	530	42.00	77.70	40.58	0.154	13.49
6/30/92	9:00	25	485	56.00	103.60	113.67	0.188	27.27
7/08/92	14:00	20	680	13.97	25.84	310.33	0.066	40.19
7/17/92	15:10	60	678	10.03	18.56	526.50	0.047	50.38
7/22/92	10:16	0	658	10.11	18.70	641.60	0.046	55.68
7/28/92	9:25	70	620	15.14	28.01	783.58	0.065	64.92
8/06/92	15:31	11520	728	8.08	14.95	813.68	0.041	66.15
8/12/92	11:25	720	673	6.66	12.32	941.58	0.031	70.12
8/19/92	10:50	15	600	12.48	12.48	1108.75	0.028	74.81
8/26/92	10:30	0	595	12.19	12.19	1276.42	0.027	79.36
9/03/92	20:07	0	579	2.63	2.63	1478.03	0.006	80.51
9/07/92	17:48	0	582	5.66	5.66	1571.72	0.012	81.67
9/12/92	15:07	40	579	3.14	3.14	1688.37	0.007	82.46
9/17/92	19:49	0	523	4.06	4.06	1813.07	0.008	83.46
10/10/92	16:21	32693	0	4.32	4.32	1816.72	0.000	83.46



TREATMENT SYSTEM PERFORMANCE (CONT.)**Treatment Performance Data [2, 3, 6, 21, 22] (cont.)**

Table 7 (cont.). SVE System Operation Log [6]

Date	Time	Down Time (min)	Qs (scfm)	CCI4 @ S-101 (ug/L)	Corrected CCI4 @ S-101 (ug/L)	Time of Operation (hrs)	CCI4 Extraction Rate (lb/hr)	Total CCI4 Removed (lb)
10/19/92	13:00	0	655	3.24	3.24	2029.37	0.008	85.15
10/25/92	17:29	0	583	2.52	2.52	2177.85	0.006	85.96
10/31/92	15:40	30	574	2.95	2.95	2319.53	0.006	86.86
11/07/92	14:00	0	520	2.29	2.29	2485.87	0.004	87.60
11/17/92	17:32	19	504	2.47	2.47	2729.08	0.005	88.74
11/12/92	11:06	0	502	2.21	2.21	2866.65	0.004	89.31
11/28/92	12:06	0	512	1.03	1.03	2987.65	0.002	89.55
12/01/92	17:00	0	519	1.04	1.04	3064.55	0.002	89.70
12/05/92	12:57	0	523	1.37	1.37	3156.50	0.003	89.95
12/12/92	12:29	25	507	1.51	1.51	3323.62	0.003	90.43
12/23/92	11:34	40	659	0.49	0.49	3586.03	0.001	90.75
12/30/92	16:36	0	669	0.12	0.12	3759.07	0.0003	90.80
2/06/93	13:52	47760	858	0.13	0.13	3872.33	0.0004	90.85
3/04/93	13:08	37380	538	0.67	0.67	3872.60	0.0014	90.85
3/06/93	16:48	0	708	0.11	0.11	3924.27	0.0003	90.86
3/13/93	16:39	0	547	1.63	1.63	4092.12	0.0033	91.42
3/23/93	16:31	440	562	0.39	0.39	4324.65	0.0008	91.61
4/03/93	14:19	0	767	0.57	0.57	4586.45	0.0016	92.04
4/10/93	16:22	0	757	0.38	0.38	4756.50	0.0011	92.23
4/17/93	16:22	17	743	0.30	0.30	4924.22	0.0008	92.37
4/24/93	16:22	0	743	0.27	0.27	5092.22	0.0008	92.49
5/01/93	16:30	0	663	0.17	0.17	5260.35	0.0004	92.56
5/08/93	17:12	50	724	0.26	0.26	5428.22	0.0007	92.68
5/16/93	17:12	0	708	0.00	0.00	5620.22	0.0000	92.68
5/22/93	17:12	0	703	0.12	0.12	5764.22	0.0003	92.73
6/15/93	14:03	3515	661	0.06	0.06	6278.48	0.0001	92.80
6/17/93	12:54	0	671	0.22	0.22	6325.33	0.0006	92.83
6/27/93	17:24	3600	687	0.03	0.03	6509.83	0.0001	92.84



TREATMENT SYSTEM PERFORMANCE (CONT.)

Treatment Performance Data [2, 3, 6, 21, 22] (cont.)

Figure 8. Carbon Tetrachloride Mass Extraction Rate vs. Time [Adapted from Reference 6]

Figure 9. Cumulative Mass of Carbon Tetrachloride Removed vs. Time [Adapted from Reference 6]



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TREATMENT SYSTEM PERFORMANCE (CONT.)

Treatment Performance Data (cont.)

Table 8. Carbon Tetrachloride Concentrations ($\mu\text{g/L}$) from On-site Analysis of Extracted Air Samples [6]

Sample Location	June 25 1992	July 28 1992	August 6 1992	September 12 1992	October 10 1992	November 23 1992
SVE-1S	5.00	0.0	0.0	0.0	0.2	0.0
SVE-1D	240.1	11.6	8.8	9.6	10.2	4.0
SVE-3S	7.8	0.0	0.0	0.0	0.0	0.1
SVE-4I	42.3	0.0	0.0	0.0	0.4	0.0
SVE-4D	184.8	0.0	13.4	4.3	8.4	1.4
SVE-5I	263.9	4.9	9.5	0.2	2.0	0.6
SVE-5D	224.3	15.9	21.6	6.9	2.8	2.6
SVE-6I	56.4	2.7	3.8	0.3	1.0	0.0
SVE-6D	82.7	13.0	9.3	1.2	1.6	0.6
S-101*	88.8	28.0	15.0	4.1	4.3	2.2
Sample Location	December 23 1992	February 6 1993	April 3 1993	May 1 1993	June 17 1993	
SVE-1S	0.0	0.1	0.0	0.0	0.0	
SVE-1D	4.0	0.0	1.3	1.0	0.4	
SVE-3S	0.0	0.0	0.0	0.0	NS	
SVE-4I	0.0	0.0	0.0	0.0	NS	
SVE-4D	1.3	0.0	0.0	0.2	0.2	
SVE-5I	0.0	0.4	0.1	0.2	0.0	
SVE-5D	0.4	0.0	0.2	0.5	0.1	
SVE-6I	0.1	0.1	0.0	0.0	0.0	
SVE-6D	0.6	0.0	0.1	0.1	0.0	
S-101*	0.5	0.1	0.6	0.3	0.2	

*S-101 is the carbon system inlet.

NS = Not sampled

Note: A correction factor of 1.85 was applied to on-site GC results obtained before August 12, 1992 to account for negative bias.

Table 9. Results of Canister Samples [6]
Canister Results for March 4, 1993

Contaminant	Concentration at Extraction Well SVE-1D ($\mu\text{g/L}$)	Concentration at Extraction Well SVE-5D ($\mu\text{g/L}$)	Concentration at Extraction Well SVE-5I ($\mu\text{g/L}$)
Carbon Tetrachloride	1.80	0.92	0.52
Chloroform	0.12	0.04	0.13
Benzene	0.17	0.18	0.01
Trichloroethene	1.10	7.20	1.20
1,1-DCE	1.10	5.20	0.98
1,1,1-TCA	0.95	4.60	0.83
PCE	1.40	5.90	1.10
Methylene Chloride	0.10	0.16	0.43



TREATMENT SYSTEM PERFORMANCE (CONT.)

Treatment Performance Data (cont.)

Table 9. (cont.) Results of Canister Samples [6]
Canister Results for March 6, 1993

Contaminant	Concentration at Extraction Well SVE-1D ($\mu\text{g/L}$)	Concentration at Extraction Well SVE-5D ($\mu\text{g/L}$)	Concentration at Extraction Well SVE-5I ($\mu\text{g/L}$)
Carbon Tetrachloride	1.90	Non-Detect	0.37
Chloroform	0.11	Non-Detect	0.12
Benzene	0.32	Non-Detect	Non-Detect
Trichloroethene	5.40	Non-Detect	Non-Detect
1,1-DCE	4.00	Non-Detect	Non-Detect
1,1,1-TCA	3.60	Non-Detect	Non-Detect
PCE	5.10	Non-Detect	Non-Detect
Methylene Chloride	0.13	0.18	Non-Detect

Table 9. (cont.) Results of Canister Samples [6]
Canister Results for May 1, 1993

Contaminant	Concentration at Extraction Well Carbon Inlet, S-101 ($\mu\text{g/L}$)	Concentration at Extraction Well SVE-5D ($\mu\text{g/L}$)
Carbon Tetrachloride	0.33	0.64
Chloroform	Non-Detect	Non-Detect
Benzene	0.05	Non-Detect
Trichloroethene	5.30	4.90
1,1-DCE	2.80	2.50
1,1,1-TCA	2.50	2.10
PCE	3.00	2.60

Performance Data Assessment

A review of the results in Table 7 and Figures 8 and 9 indicates that after approximately 3,600 hours of operation, the SVE system achieved the extraction rate cleanup goal of 0.001 lb/hr, with a corresponding mass of carbon tetrachloride removed equal to approximately 90 pounds. The results indicate that more than half of the mass removed occurred during the first 22 days of operation, and that the concentration of carbon tetrachloride at the wellheads sharply decreased after the first month of operation.

To verify that the carbon tetrachloride cleanup goal was achieved, the system was shut down for 2 months to assess the potential rebound in the carbon tetrachloride concentration. As shown in Table 7, there was no significant increase in the carbon tetrachloride concentrations after a 2-month shutdown.

The rapid decrease in carbon tetrachloride concentration is further supported by the information in Table 8, which shows a decrease in CCl_4 concentration by at least one order of magnitude from June 25 to



TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (cont.)

July 28, 1992 for seven of eight sample locations, followed by a more gradual decrease in concentrations through June 17, 1993. The results in Table 9 show that, in addition to CCl_4 , detectable levels of chloroform, benzene, trichloroethene, 1,1-dichloroethene (DCE), 1,1,1-trichloroethane (TCA), tetrachloroethene (PCE), and methyl-

ene chloride were present in the extracted vapors from wells 1D, 5D, and 5I. Also, as shown in Tables 8 and 9, the CCl_4 concentrations measured on May 1, 1994 using on-site analyses and canister samples were within 25% of each other for sampling locations S-101 (0.3 vs. 0.33 $\mu\text{g/L}$) and Well-5D (0.5 and 0.64 $\mu\text{g/L}$).

Performance Data Completeness

Data characterize concentrations of contaminants in soil vapors from each extraction well over the course of the treatment operation,

and show how treatment performance varies with operating conditions of the SVE system.

Performance Data Quality [12]

A comparison of the on-site syringe results, performed in August 1992, with the canister results showed that the syringe results were biased low. The bias is believed to be a result of diffusion of the sample from the syringe prior to analysis. A larger sample injection volume was used to minimize the diffusion effect. A correction factor of 1.85 was developed for the syringe results based on studies done with larger injection volumes and the canister results.

Other exceptions noted by the vendor for this treatment application included:

In February 1993, a negative bias was also observed and verified by the March sampling.

It was determined that the following reasons could have contributed to this bias:

- Simple sampling equipment (10-mL syringe versus 6-L SUMMA™ canisters);
- Low levels of contaminants in the samples (at higher concentrations, small fluctuations are not so dramatic);
- Cold weather conditions; and
- The on-site laboratory and analytical methodology was limited, whereas the off-site analyses were performed by an EPA region laboratory.

TREATMENT SYSTEM COST

Procurement Process [2]

EPA's ARCS contractor, Morrison-Knudsen Corporation (MK), was assigned the Remedial Design phase work for this action. MK was also retained to develop the A/E bid packages, to provide oversight of the construction of the treatment system, and to operate the SVE system during the shakedown period. MK contracted with a drilling firm as a subcontractor

to install the new extraction and monitoring wells and procured the GAC through a vendor. MK also issued subcontracts for fabrication of the skid-mounted vacuum extraction unit and for on-site construction operations support. All of the subcontracts were obtained through competitive bidding.



TREATMENT SYSTEM COST (CONT.)

Treatment System Cost

In order to standardize reporting of costs across projects, the treatment vendor's costs were categorized according to an interagency Work Breakdown Structure (WBS), as shown in Table 10. The WBS contains specific elements for activities directly attributed to treatment. No costs were reported by the vendor for before- or after-treatment activities, including monitoring, sampling, testing, and analysis.

Table 11 presents the actual costs for construction, operation, and decommissioning of the SVE system, according to a format provided by the treatment vendor.

As shown in Tables 10 and 11, actual costs for this application were approximately \$370,000. This value is 17% less than the \$447,700 value originally estimated for this application. [21, 22]

The actual total treatment cost value of \$370,000 corresponds to \$620 per pound of CCl_4 removed (600 pounds CCl_4 removed) and \$2.00 per cubic yard of soil treated. The number of cubic yards of soil treated at Hastings is an estimate based on information provided by the vendor; the actual amount of soil treated is not available at this time for comparison with the estimate.

Table 10. Actual Costs Shown According to the WBS [adapted from 21]

Mobilization/Setup (well installation, SVE construction, and vacuum extraction unit fabrication)	\$175,404
Operation (short-term; up to 3 years) (project monitoring and control, procurement support, construction management, technical engineering services, and O&M services)	\$159,250
Cost of Ownership (GAC, gas chromatograph lease, rolloff bin rental, and award fee)	\$31,594
Dismantling (decommissioning)	\$3,380
TOTAL TREATMENT COSTS	\$369,628

Cost Data Quality

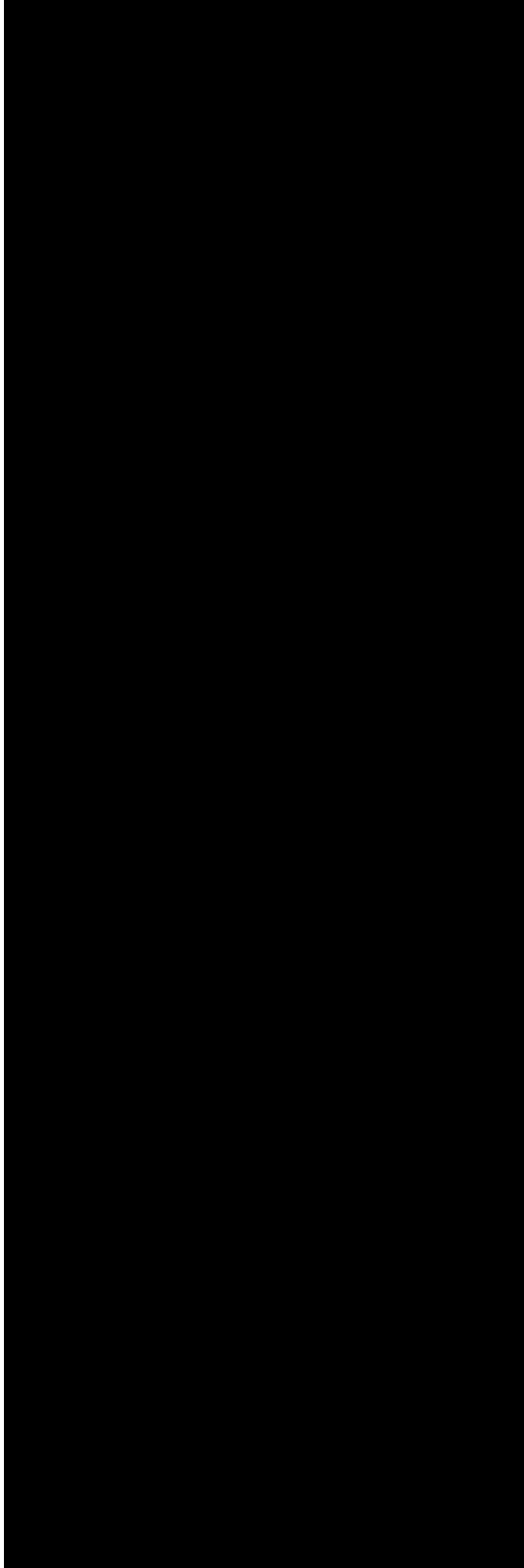
A detailed breakdown of the cost elements and actual cost data were provided by the vendor for this application. Costs were provided for labor, equipment, subcontracts, travel, other direct costs, and fees. Costs were

provided for project monitoring and control, procurement support, construction management, technical engineering services, and award fee.



TREATMENT SYSTEM COST (CONT.)**Treatment System Cost (cont.)**

Table 11: Actual Costs for Construction, Operation, and Decommissioning [21]


Notes:

- a- Work included under the Project Monitoring & Control task included accounting, cost and schedule tracking, labor and cost distribution, and other administrative functions. Procurement Support was primarily associated with purchasing and engineering oversight of the vacuum extraction unit, carbon adsorbers, gas chromatograph, and other supplies. Construction Management involved field installation and decommissioning activities including drilling, construction, system dismantlement, and grouting of the wells. Technical Engineering Services included operations, maintenance, and reporting functions during remediation.
- b- Major equipment expenditures included granular activated carbon (\$11,364.66), gas chromatograph lease (\$475.61 per month), and rolloff bin rental and soils disposal (\$1677.66).
- c- Subcontracts included:
- | | |
|--|-------------|
| Initial well installation by Boyles Brother Drilling | \$31,907.60 |
| SVE construction by Carmichael Construction | \$65,958.00 |
| Vacuum extraction unit fabrication by Hydrologics | \$73,810.00 |
| O&M services by Carmichael Construction | \$ 3,421.00 |
| Decommissioning by Carmichael Construction | \$ 3,380.00 |
| Well grouting by J& Drilling | \$ 3,728.00 |
- d- Other direct costs included phone, mail, computer time, reproduction, insurance, and electric bills. Electricity costs were as high as \$1,200.00 per month during full time operation.



OBSERVATIONS AND LESSONS LEARNED

Cost Observations and Lessons Learned

- Actual costs for installing and performing the SVE application, including disposal costs for the GAC, at the Well Number 3 Subsite were approximately \$370,000, which corresponds to \$620 per pound of CCl_4 removed (600 pounds CCl_4 removed) and \$2.00 per cubic yard of soil treated.
- Actual costs were 17% less than originally estimated. According to the RPM, cost savings were realized in the following areas:
 1. The SVE system worked better than expected, removed the contamination faster than expected, and was on-line about 2/3 of the time.
 2. Savings were realized by using local construction contractors to provide oversight during the operation phase of the system. The involvement of the ARCS contractor was limited to phone conversations. Limited site travel was required during remediation phase. Costs were saved by utilizing a local chemist to perform chemical monitoring, and by utilizing a Region VII laboratory to provide off-site analysis.
 3. The strong partnership, involvement, and commitment, between EPA and the State of Nebraska on this project allowed operating decisions to be based upon system performance and through an interactive decision-making process.
 4. The ability to use one contract vehicle from design to project completion. One ARCS contractor designed the system and then performed project oversight. Subcontractors procured by the ARCS contractor performed well.

Performance Observations and Lessons Learned

- Soil vapor extraction met the remedial action cutoff extraction rate (0.001 lbs/hr) to remove carbon tetrachloride contamination at this operable unit within approximately 6 months of system operation. No CCl_4 rebounding effects were observed after a 2-month shutdown period.
- More than half of the contaminant removal occurred during the first 22 days of system operation.
- The RPM indicated that it is likely that the mass of VOCs removed by the system was greater than shown by the field results, based on the following information:
 1. The EE/CA determined that 400 pounds of CCl_4 was estimated to be present;
 2. Results from Westates Carbon determined that the three GAC canisters contained 19% VOCs (approximately 570 pounds of VOCs);
 3. The use of 10-mL syringes to collect gas samples from the vacuum side of the system during operation (approximately 7 in. of Hg); and
 4. The off-site confirmation testing which indicated that the on-site sampling had a negative bias of approximately 50%.

In addition, the RPM indicated that the on-site gas collection method, while quick and inexpensive, likely resulted in the dilution of the gas



OBSERVATIONS AND LESSONS LEARNED (CONT.)

Performance Observations and Lessons Learned (cont.)

sample during sample collection. The RPM estimated that a total of approximately 600 pounds of CCl_4 were removed by the SVE system at the

Well Number 3 Subsite during both the treatability study phase and the remedial action phase.

Other Observations and Lessons Learned

- The full-scale system, designed based on the results of the treatability study, was implemented without modification. The treatability study results predicted that a 2-year operation period would be required to remediate the site. The full-scale system achieved the cleanup goals in less than a year.
- For the soils at Hastings, modelling was not reflective of system performance. The modelling predicted a radius of influence of 300 feet for the SVE wells; however, the actual radius of influence was found to be at least 1,500 feet for the system (based on an analysis of the source for additional contaminants removed by the SVE system).
- The on-site analytical protocol was not reflective of actual contaminant concentrations in the extracted soil vapors towards the end of the remediation (i.e., for lower concentrations of VOCs). For lower VOC concentrations, a larger sample volume is needed (e.g., a 6-liter SUMMA™ canister).
- According to the RPM, the SVE system was sufficiently flexible to allow the sequential pumping of the system. Sequential pumping was desirable for the following reasons:
 1. When two or more wells are located close enough to each other that their areas of vacuum influence overlap, a small "dead zone" will occur where soil gas will not move toward either well; and
 2. After an extended pumping period, the rate of VOC diffusion from the soil or soil pore water matrix to the soil gas may become the limiting factor in the ability to remove VOCs from the vadose zone (the system becomes "diffusion limited"). In this case it is usually beneficial to stop pumping to allow time for equilibrium to be established between the VOCs in the soil/pore water matrix and the surrounding soil gas (i.e., rebounding).
- EPA issued the ROD for groundwater Operable Unit 13 on June 30, 1993, which required groundwater extraction and treatment. EPA initiated a groundwater 30-day treatability study in April 1994 utilizing monitoring well CW-1. Groundwater monitoring results indicated that the levels of CCl_4 found in monitoring well CW-1 varied from a high of 1,400 $\mu\text{g/L}$ (one time), to levels between 100-150 $\mu\text{g/L}$ prior to EPA's treatability SVE action. Levels continued to drop and in June 1993 were approximately 20 $\mu\text{g/L}$. During EPA's 39-day treatability study/pump test, using monitoring well CW-1, the levels of CCl_4 in the well averaged less than 5 $\mu\text{g/L}$. [22]



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3. U.S. Environmental Protection Agency. Remedial Action Report for Source Control Operable Unit at the Well #3 Subsite, Hastings, Nebraska, June 17, 1993.
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5. Letter from Diane Easley, EPA to Richard Schlenker, NDEQ, dated December 1, 1992.
6. Morrison-Knudsen Corporation. "Well Number 3 Source Control, Remedial Design/Remedial Action - May/June 1993 Monthly Status Report," U.S. EPA ARCS, July 7, 1993.
7. Morrison-Knudsen Corporation. "Well Number 3 Source Control, Remedial Design/Remedial Action - April 1993 Monthly Status Report," U.S. EPA ARCS, May 3, 1993.
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9. Morrison-Knudsen Corporation. "Well Number 3 Source Control, Remedial Design/Remedial Action - December 1992/January 1993 Monthly Status Report," U.S. EPA ARCS, January 4, 1994.
10. Morrison-Knudsen Corporation. "Well Number 3 Source Control, Remedial Design/Remedial Action - November 1992 Monthly Status Report," U.S. EPA ARCS, December 9, 1992.
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19. Morrison-Knudsen Corporation. "Well Number 3 Source Control, Remedial Design/Remedial Action - December 1991/January 1992 Monthly Status Report," U.S. EPA ARCS, February 5, 1992.



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20. Interim Action Record of Decision, Hastings Ground Water Contamination Site, Well #3 Subsite, Groundwater Operable Units, Plume 1 Operable Unit #3, Plume 2, Operable Unit #18, Hastings, Nebraska, U.S. EPA Region VII, Kansas City, Kansas, June 30, 1993.
21. Comments submitted by Morrison-Knudsen Corporation, on January 26, 1995.
22. Comments submitted by Diane Easley of EPA Region VII on February 9, 1995.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Radian Corporation under EPA Contract No. 68-W3-0001.



APPENDIX A - TREATABILITY STUDY

SUMMARY

Identifying Information	
Site Location:	Hastings, Nebraska
ROD Date:	9/26/89
Historical Activity at Site – SIC Codes:	0723A (Crop Preparation Services for Market Except Cotton Ginning – Grain Fumigation)
Historical Activity at Site – Management Practices:	Spill/Contaminated Aquifer
Site Contaminants:	Carbon Tetrachloride (CCl ₄) and Chloroform
Type of Action:	Remedial
Did ROD include a contingency based on treatability study results?	No
Treatability Study Information	
Type of Treatability Study:	Pilot
Duration of Treatability Study:	4/15/91 to 5/9/91
Media Treated:	Soil (in situ)
Quantity Treated:	45 pounds of VOCs removed
Treatment Technology:	Soil Vapor Extraction (SVE)
Target Contaminant of Concern:	Carbon Tetrachloride
Conducted before the ROD was signed:	No
Additional treatability studies conducted:	No
Technology selected for full-scale application:	Yes
Treatability Study Strategy	
Number of Runs:	Three operational tests (step, steady-state, and gas tracer) were performed
Key Operating Parameters Varied:	Vacuum applied, treatment time, air flow rate
Treatability Study Results:	
Mass of Contaminants Removed:	45 pounds of CCl ₄ and chloroform from four wells
Pre-test Soil Vapor Concentrations: (measured by on-site laboratory)	0.3 µg/L to 440 µg/L of CCl ₄ 0.01 µg/L to 250 µg/L of chloroform
Post-test Soil Vapor Concentrations: (measured by on-site laboratory)	Non-detectable to 2.0 µg/L of CCl ₄ 0.002 µg/L to 2.0 µg/L of chloroform
Correlation of Operating Parameters with Performance Data:	Greater treatment time resulted in higher mass of contaminant removed; removal of contaminants was higher in deep wells compared to shallow wells



APPENDIX A - TREATABILITY STUDY (CONT.)

TREATABILITY STUDY STRATEGY

Treatability Study Purpose [4]

The overall purposes of the pilot-scale treatability study were to:

- Collect data on the removal rate of carbon tetrachloride (CCl_4) and chloroform by the pilot SVE system in order to develop full-scale treatment system design criteria; and
- Collect data to project time and effectiveness of full-scale treatment system performance of the SVE system.

Specific objectives of the treatability study included determination of well spacing and well screening intervals for full-scale application, evaluation of full-scale flow rate, vacuum and granular activated carbon (GAC) requirements, estimation of cost and time required for full-scale remediation, and collection of additional subsurface condition data that could affect full-scale design. In addition, concentrations of CCl_4 and chloroform in the extracted soil vapor was also measured.

TREATMENT SYSTEM DESCRIPTION

Treatment System Description and Operation [4]

Treatment System Description

As shown in Figure A-1, the SVE pilot treatment system included four vapor extraction wells and two monitoring wells. Two extraction wells (SVE-1S and SVE-2S) were designed to study the shallow zone, and two extraction wells (SVE-1D and SVE-2D) were designed to study the deep zone.

Shallow and deep monitoring wells (MP-1S and MP-1D) were 4 inches in diameter and equipped with several probes at various depths. The well casings were schedule 80, polyvinyl chloride (PVC) casings with 0.01-inch slot wire wrapped stainless steel screens, except for SVE-1S which had a 0.01-inch PVC screen. As shown in Figure A-2, the extraction wells were piped to an air/water separator, vacuum pump/blower, and two 1,000-lb activated carbon canisters. The treated vapors were discharged to the air through a 20-foot high stack.

Operational Tests

Three operational tests (step, steady-state, and gas tracer) were performed for 10 days on each well within the shallow and deep zones. During the tests, the vacuum was varied to optimize performance of the shallow and deep wells. The step test was conducted

by pumping each well at incrementally increasing vacuums to observe the flow rate response. Results of the step test were used to determine a flow rate for the second phase, a steady-state test. The step test results were also used to establish design criteria for extraction wells, pumping, and vapor treatment equipment required for full-scale remediation. The steady-state test was conducted, per the conditions determined in the step test, to study removal rate of contaminants (CCl_4 and chloroform). At the end of the steady-state test, the gas tracer test was conducted to evaluate soil gas velocities and to calculate permeability to air.

Wells SVE-1D and SVE-1S were operated for approximately 200 hours each and wells SVE-2D and SVE-2S were operated for approximately 50 hours each. A total of 45 pounds of volatile organic compounds were captured by the granular activated carbon system during the treatability study.

Pretest, operational, and post-test sampling and analysis were performed by both on-site (Close Support Laboratory or CSL) and off-site laboratories (Contract Laboratory Program or CLP). Samples of soil, extracted soil vapor, carbon outlet gas, and water from the air/water separator were also collected and analyzed. Syringe samples were collected for analysis by the CSL, canister samples were collected for analysis by CLP.



APPENDIX A - TREATABILITY STUDY (CONT.)

TREATMENT SYSTEM DESCRIPTION (cont.)

Figure A-1. SVE Test Cell Layout [4]

Figure A-2. General Schematic of the SVE Treatment System [4]



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APPENDIX A - TREATABILITY STUDY (CONT.)

Procurement Process/Treatability Study Cost [4]

Morrison-Knudsen Corporation Environmental Services, under Alternative Remedial Contracts Strategy (ARCS) Contract Number 68-W9-0025, in conjunction with EPA Region VII, EPA Ada Laboratory, and the NDEQ, conducted the treatability study as the first phase of the

Remedial Design of the Hastings Well Number 3 Subsite. The cost of the treatability study and remedial design was approximately \$400,000. Projected full-scale treatment costs are discussed below.

TREATABILITY STUDY RESULTS

Operating Parameters and Performance Data [4]

The operating parameters for the step and steady-state tests conducted during the treatability study are shown in Table A-1.

Data on total mass removed and post-test concentrations of CCl_4 in extracted soil vapor are presented in Figures A-3 to A-10 for the four extraction wells (SVE-1D, SVE-2D, SVE-1S,

and SVE-2S). These results are summarized in Table A-2.

Table A-3 compares results of the pre-test and post-test analyses of soil vapor samples collected at the site. Results for both off-site and on-site analyses for CCl_4 and chloroform are presented for samples collected from the four extraction wells and seven monitoring probe locations.

Table A-1. Operating Parameters for the Pilot-Scale SVE Treatability Study at the Hastings Well Number 3 Subsite [4]

Operational Test	SVE-1D	SVE-2D	SVE-1S	SVE-2S
Step Test (Up)	2.85	2.85	3.06	—
Applied Vacuum at Well Head (in. Hg)	5.30	6.21	6.52	—
	6.92	9.19	9.37	—
	8.55	12.63	12.63	—
	11.41		14.66	—
	11.81		12.02	—
Step Test (Down)	10.08	—	13.85	—
Applied Vacuum at Well Head (in. Hg)	7.33	—	9.17	—
	5.70	—	6.52	—
	3.26	—	3.06	—
Observed Flow Rates at Well (scfm)	65 (min.) 205 (max.)	65 (min.) 175 (max.)	48 (min.) 178 (max.)	— —
Duration of Step Test (hours)	30.17	6.17	27.43	—
Steady-State Applied Vacuum at Well Head (in. Hg)	11.8	11.8	11.4	13
Duration of Steady-State Test (hours)	168	48	168	48
Total Operating Time (hours)	198.17	51.17	195.43	48



APPENDIX A - TREATABILITY STUDY (CONT.)

TREATABILITY STUDY RESULTS (cont.)

Figure A-3. Total Mass Removed in Extraction Well SVE-1D
Carbon Tetrachloride & Chloroform (Based on CSL Results) [4]

Figure A-4. Concentration of Carbon Tetrachloride in Extraction
Well SVE-1D (Based on CSL Results) [4]

Figure A-5. Total Mass Removed in Extraction Well SVE-2D
Carbon Tetrachloride and Chloroform (Based on CSL Results) [4]

Figure A-6. Concentration of Carbon Tetrachloride in Extraction
Well SVE-2D (Based on CSL Results) [4]

Figure A-7. Total Mass Removed in Extraction Well SVE-1S
Carbon Tetrachloride and Chloroform (Based on CSL Results) [4]

Figure A-8. Concentration of Carbon Tetrachloride in Extraction
Well SVE-1S (Based on CSL Results) [4]

Figure A-9. Total Mass Removed in Extraction Well SVE-2S
Carbon Tetrachloride and Chloroform (Based on CSL Results) [4]

Figure A-10. Concentration of Carbon Tetrachloride in
Extraction Well SVE-2S (Based on CSL Results) [4]



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APPENDIX A - TREATABILITY STUDY (CONT.)

TREATABILITY STUDY RESULTS (cont.)

Table A-2. Summary of CCl_4 and Chloroform Mass Removal by the SVE System [4]

Well	Duration of SVE System Operation (hrs)	Mass of CCl_4 and Chloroform Extracted (lbs)	Post-Test Concentration (CSL) of CCl_4 in Extracted Soil Vapors ($\mu\text{g/L}$)
SVE-1D	198.17	35	80
SVE-2D	51.17	3	12
SVE-1S	195.43	6	1.0
SVE-2S	48	0.5	32
Total	-	44.5	-

CSL - Close Support Laboratory (on-site).

Table A-3. Comparison of Pre-Test and Post-Test Soil Vapor Concentrations of CCl_4 and Chloroform [4]

			CLP Results		CSL Results	
			CCl_4 ($\mu\text{g/L}$)	Chloroform ($\mu\text{g/L}$)	CCl_4 ($\mu\text{g/L}$)	Chloroform ($\mu\text{g/L}$)
SVE-1D	Pre-Test	04/15/91	20	0.39	440	1
	Post-Test	04/26/91	48	1.8	80	0.2
SVE-2D	Pre-Test	04/15/91	100	1.1	0.3	ND
	Post-Test	04/26/91	9.4	0.11	12	0.1
SVE-1S	Pre-Test	04/15/91	100	28	11	0.12
	Post-Test	05/09/91	1.7	ND	1.0	0.3
SVE-2S	Pre-Test	04/15/91	130	3.1	40	2
	Post-Test	05/09/91	48	1.8	32	0.9
MP-1D-D	Pre-Test	04/15/91	360	5	31	ND
	Post-Test	04/26/91	280	4.1	250	2.0
MP-1D-E	Pre-Test	04/15/91	540	5.3	270	0.9
	Post-Test	04/26/91	200	3.3	240	2.0
MP-1D-F	Pre-Test	04/15/91	480	4.3	64	0.4
	Post-Test	04/26/91	240	1.8	190	1.0
MP-1D-G	Pre-Test	04/15/91	200	1.6	19	0.2
	Post-Test	04/26/91	190	0.96	110	0.5
MP-1S-A	Pre-Test	04/15/91	130	2.6	30	0.7
	Post-Test	05/09/91	ND	ND	0.3	0.003
MP-1S-B	Pre-Test	04/15/91	240	4.8	38	0.5
	Post-Test	05/09/91	ND	ND	0.3	0.005
MP-1S-C	Pre-Test	04/15/91	250	5.1	21	0.8
	Post-Test	04/26/91	ND	ND	0.01	0.002

CLP - Contract Laboratory Program (off-site).

CSL - Close Support Laboratory (on-site).

ND - Not detected.



APPENDIX A - TREATABILITY STUDY (CONT.)

TREATABILITY STUDY RESULTS (cont.)

Performance Data Assessment

A review of the data shown in Table A-2 indicates that a total of 38 pounds of CCl_4 and chloroform were extracted from the deep wells (35 pounds from SVE-1D and 3 pounds from SVE-2D). A total of 6.5 pounds of CCl_4 and chloroform were extracted from the shallow wells (6 pounds from SVE-1S and 0.5 pounds from SVE-2S). The deep well that operated for approximately 200 hours extracted 35 pounds of CCl_4 and chloroform compared to the shallow well that extracted 6 pounds of contaminants, and the deep well that operated approximately 50 hours extracted 3 pounds of CCl_4 and chloroform compared to the shallow well that extracted 0.5 pounds of contaminants.

Figures A-3, A-5, A-7, and A-9 indicate that removal of CCl_4 and chloroform from each well increased from the start to finish of each test; however, Figures A-4, A-5, A-8, and A-10 indicate that the measured concentrations of CCl_4 in the four extraction wells fluctuated throughout the SVE system operation. For example, during the steady-state test on SVE-1D, soil gas concentrations were measured as high as 1,700 $\mu\text{g/L}$ and were reduced to approximately 200 $\mu\text{g/L}$ after 168 hours of operation (shown on Figure A-4).

Concentrations of CCl_4 measured in soil vapor samples ranged from 20 $\mu\text{g/L}$ to 540 $\mu\text{g/L}$ pre-test, and ranged from non-detectable to 280 $\mu\text{g/L}$ post-test, as reported by CLP. As reported by CSL, CCl_4 concentrations ranged from 0.3 $\mu\text{g/L}$ to 440 $\mu\text{g/L}$ pre-test, and ranged from 0.01 $\mu\text{g/L}$ to 250 $\mu\text{g/L}$ post-test.

Concentrations of chloroform measured in soil vapor samples ranged from 0.39 $\mu\text{g/L}$ to 28 $\mu\text{g/L}$ pre-test, and ranged from non-detectable to 4.1 $\mu\text{g/L}$ post-test, as reported by CLP. As reported by CSL, chloroform concentrations ranged from non-detectable to 2 $\mu\text{g/L}$ pre-test, and ranged from 0.002 $\mu\text{g/L}$ to 2.0 $\mu\text{g/L}$ post-test.

Soil gas ranges in pre-test/post-test soil vapor sample analyses as reported by CLP indicate that concentrations of CCl_4 and chloroform

decreased in ten of the eleven locations tested as reported by CLP. Concentrations decreased for only seven of the eleven CCl_4 samples, and for four of the eleven chloroform samples, as reported by CSL.

Performance Data Completeness

Data characterize concentrations of contaminants in soil vapors from each extraction well over the course of the treatability study, and show how treatment performance varies with operating conditions of the SVE system.

Performance Data Quality [4]

Quality assurance procedures of the on-site laboratory included decontamination procedures for sample equipment, calibration checks on analytical equipment, use of calibration standards, analysis of water blanks, and use of EPA audit samples. Off-site analyses were performed as specified by the CLP program. No exceptions to the QA/QC protocol were noted by the vendor.

Projected Full-Scale Treatment

Application Design [2]

A preliminary design for a full-scale SVE treatment system was provided by Morrison-Knudsen, based on the results of the treatability study, as shown in Table A-4. The full-scale system was designed to include three new deep and intermediate extraction wells and three new deep monitoring probes in addition to the existing pilot-scale SVE system. One shallow well was intended to be replaced by a new shallow well; otherwise, the entire pilot-scale system was intended to be used in full-scale treatment application.

SVE was implemented at the Hastings Well Number 3 Subsite. The preceding report presents observations and lessons learned concerning the full-scale application, including observations concerning the results of the treatability study.



APPENDIX A - TREATABILITY STUDY (CONT.)**TREATABILITY STUDY RESULTS (cont.)**

Table A-4. Preliminary Design for Full-Scale SVE System at the Hastings Well Number 3 Subsite [2]

Design Parameter	Value
Extraction Wells	
Screened intervals of three wells:	20-40 feet (shallow) 50-80 feet (intermediate) 80-110 feet (deep)
Radius of influence:	100 feet
Wellhead vacuum:	3 in. Hg
Flow Rate per well pair:	300 scfm
Well Diameter:	4 inches
Soil Gas Conditions at Wellhead	
Carbon tetrachloride, maximum:	1,800 µg/L
Carbon tetrachloride, average:	100 µg/L
Chloroform, maximum:	30 µg/L
Chloroform, average:	3 µg/L
Temperature:	50° F
Relative humidity:	100%
Pressure, absolute:	25 in. Hg
Maximum total flow rate:	900 scfm 1,300 acfm
GAC System Criteria	
Removal capacity:	0.2 lb CCl ₄ /lb GAC
Maximum total flow rate:	1,300 acfm
Number of adsorbers per stage:	3
Number of stages:	2
Total number of adsorbers:	6
Adsorber diameter:	42" min.
Adsorber face velocity:	60 ft/min (max)
Mass of GAC per adsorber:	1,000 lb
Total mass of GAC:	6,000 lb
Total adsorber capacity:	1,200 lb CCl ₄
Vacuum Pump Criteria	
Maximum total flow rate:	900 scfm 1,300 acfm
Inlet vacuum:	9 in. Hg
Inlet temperature:	70° F
Outlet pressure:	23 in. H ₂ O
Site Design Conditions	
Elevation:	1,900 ft
Barometric pressure:	28 in. Hg
Wind loading:	80 mph
Mean ambient temperature:	50° F
Minimum ambient temperature:	-30° F
Maximum ambient temperature:	110° F



APPENDIX A - TREATABILITY STUDY (CONT.)

TREATABILITY STUDY RESULTS (cont.)

Projected Full-Scale Cost [2, 4]

Table A-5 presents estimated costs for construction and a nine-month shakedown period at the Hastings Well Number 3 Subsite. A complete breakdown of these costs was not presented in the available documentation.

Full-scale treatment activities were anticipated to require 1.5 to 2 years, with system shutdowns every three months for system performance evaluation. However, the subsequent full-scale activities did not require this length of time to achieve the treatment goals.

Table A-5. Projected Full-Scale Cost of Soil Vapor Extraction at the Hastings Well Number 3 Subsite* [2]

Capital Costs	
Item	Estimated Costs
Granular Activated Carbon	\$14,882
Modular Equipment	\$82,162
Capital Cost Subtotal	\$97,044
Operation and Maintenance (O&M) Costs	
Item	Estimated Costs
Construction	\$102,223
Architect/Engineer Construction Services	\$106,448
Nine-Month Shakedown O&M	\$141,925
O&M Cost Subtotal	\$350,596
TOTAL COST FOR CONSTRUCTION AND	\$447,640

*These costs address remedial construction and a nine-month shakedown period. No costs for operation and maintenance of the SVE system were provided in the available documentation.

OBSERVATIONS AND LESSONS LEARNED

- A total of 45 pounds of CCl_4 and chloroform were removed during the treatability study using four extraction wells. Thirty-eight pounds of CCl_4 and chloroform were extracted from the deep wells, and 6.5 pounds were extracted from the shallow wells. The deep well that operated for approximately 200 hours extracted 35 pounds of CCl_4 and chloroform compared to the shallow well that extracted 6 pounds of CCl_4 and chloroform. The deep well that operated for approximately 50 hours extracted 3 pounds of CCl_4 and chloroform compared to the shallow well that extracted 0.5 pounds of CCl_4 and chloroform.
- Concentrations of CCl_4 measured in soil vapor samples ranged from 20 $\mu\text{g/L}$ to 540 $\mu\text{g/L}$ pre-test, and ranged from non-detectable to 280 $\mu\text{g/L}$ post-test, as reported by CLP. As reported by CSL, CCl_4 concentrations ranged from 0.3 $\mu\text{g/L}$ to 440 $\mu\text{g/L}$ pre-test, and ranged from 0.01 $\mu\text{g/L}$ to 250 $\mu\text{g/L}$ post-test. Concentrations of chloroform measured in soil vapor samples ranged from 0.39 $\mu\text{g/L}$ to 28 $\mu\text{g/L}$ pre-test, and ranged from non-detectable to 4.1 $\mu\text{g/L}$ post-test, as reported by CLP. As reported by CSL, chloroform concentrations ranged from non-detectable to 2 $\mu\text{g/L}$ pre-test, and ranged from 0.002 $\mu\text{g/L}$ to 2.0 $\mu\text{g/L}$ post-test.
- Results of soil vapor analyses performed by CSL and CLP differed in the treatability study; a possible explanation for these differences is that the CSL samples were collected by syringe and the CLP samples were collected by canister.
- Design of a full-scale SVE system was based on the results from the treatability study.



COST AND PERFORMANCE REPORT

**Soil Vapor Extraction
at the
Hastings Superfund Site,
Well Number 3 Subsite
Hastings, Nebraska**



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*U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office*

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Notice

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